Data Evaluation

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Numerous topical studies of the NRC, international workshops of the CODATA, and standards development activities of the ASTM have emphasized the critical role of reliable data in both designing with advanced materials and developing new materials. The issues are two fold, beginning with the need to deduce reliable and consistent property values from diverse, seemingly inconsistent, reported values. Of equal importance is the development of the scientific basis for a general methodology or protocol by which comparable and consistent data evaluations may be pursued independently for other data of special or general interest beyond our own studies.

The issues of data evaluation are being addressed systematically in an approach that recognizes four distinguishable considerations. Each of the four aspects has useful, stand-alone results. When these individual parts are pieced together to comprise a greater whole, the result is the desired, unified methodology. The four stages of data evaluation may be identified as: (I) data collection from selected sources, (II) application of basic evaluation criteria, (III) relational analysis, and (IV) modeling. Stages I and II produce the critical underlying database, while stages III and IV establish the advanced evaluations of the data and the general methodology.

Among the central concerns of data evaluation is the need to understand significant differences among results reported independently for nominally the same properties and materials. Experience has shown that these differences are produced principally by variations in the compositions and mircrostructures of the tested specimens [1,2] or by differences in experimental procedures [3]. By focusing on relatively pure materials, we have found for polycrystalline materials that the principal microstructural effects can be resolved into considerations of grain size and shape, density (porosity or pore size and shape), and the chemical state of grain boundary phases.

In a previous study, for example, we carefully distinguished between the influences of grain size and density on fracture toughness [4] and discovered that the behavior of the critical flaw size was being interpreted incorrectly. Several studies in the literature had reported correlated variations of fracture strength and fracture toughness with the puzzling result that the flaw size was constant. Our analysis however revealed that the flaw size was not constant, but rather that its variation had been masked by concurrent variations in grain size and density.

Pursuing further the influence of microstructure, we are currently examining elastic moduli data for polycrystalline ceramics. This study has the advantage of a well known result, reconfirmed in our analysis, that the elastic moduli are not significantly affected by variations of the grain size. Consequently, we are able to focus fully on the role of density or, more conventionally, the porosity.

Previously studies, dating back more than half a century, had proposed numerous empirical or semiempirical analytical models to describe the porosity dependence. Those efforts ranged from using curves of known shapes to fit the data, to selfconsistent analyses of pores imbedded in an elastic medium. In none of those cases, however, did an analytical expression emerge in closed form from the mathematics of the derivation. Pursuing this goal to obtain a better understanding of the porosity dependence, we applied a theoretical artifice known as an effective medium.

In the effective medium theory [5], we used the classical model of an ionic solid as an idealized reference system in which all the relevant mathematics could be performed. The analysis then imposed a renormalization of the length metric to scale the ideal system to the nonideal system, and the proper retention of porosity, ϕ, was used as a consistency condition. The result proved to be a simple expression giving the explicit porosity dependence of the bulk modulus in closed form as $B = B_o(1-\phi)^m$. We have confirmed that experimental results for a wide range of ceramics indeed are compatible with this model.

[1] R. G. Munro, "Evaluated Material Properties for a Sintered α-Al_2O_3," Journal of the American Ceramic Society, Vol. 80 (8), 1919-1928 (1997).

[2] R. G. Munro, "Material Properties of a Sintered α-SiC," Journal of Physical and Chemical Reference Data, Vol. 26, No. 5, pp. 1195-1203 (1997).

[3] R. G. Munro, "Mechanical Properties" in *Handbook of Superconductivity* edited by C. P. Poole, Jr., Academic Press, pp. 569-624 (1999).

[4] R. G. Munro and S. W. Freiman, "Correlation of Fracture Toughness and Strength," Journal of the American Ceramic Society, Vol. 82, pp. 2246-2248 (1999).

[5] R. G. Munro, "Effective Medium Theory of the Porosity Dependence of Bulk Moduli," Journal of the American Ceramic Society, in press.

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